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Pesticide Morbidity in California, 1994 - 1996

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Executive Summary

This study integrated information from the major sources of health data (hospital and poison control records) with the records of the California Pesticide Illness Surveillance Program (PISP). Our goal was to obtain a clearer view both of the nature of the health effects of pesticides and of the characteristics of the individual data sources. In particular, we hoped to clarify interpretation of PISP data by estimating its completeness and by identifying characteristics associated with case identification by the PISP. In May 2004, this document was revised upon recognition that poison control records had not identified agricultural and occupational connections for some cases in which investigation had documented such connections. The change raises the estimate for agricultural exposures and lowers the estimate for non-agricultural occupational exposures.

The Central Valley Regional Poison Control Center, which served the heavily agricultural San Joaquin Valley, provided records of consultations from 1994 through 1996. The University of California Davis Medical Center Regional Poison Control Center, which served the Northeast quadrant of the state, provided records of consultations between September 1995 and December 1996.

The Office of Statewide Health Planning and Development identified discharges from nonfederal licensed California inpatient hospitals to which the hospitals had assigned codes for toxicity or chemical injury. We selected a representative sample of hospitals, and received permission to keep patient names on file until we could determine whether the hospitalization had been reported to the PISP.

We reviewed hospital and poison control records individually. Those that documented pesticide involvement were abstracted and linked to the PISP database. This produced a file with a single entry for each known case of pesticide illness or injury from 1994 through 1996.

We found that our data sources reflected very different populations. The PISP finds most of its cases through reports submitted to workers' compensation, so 5842 of its 6692 cases (87%) involved workplace exposures. Nearly 40% of PISP cases involved exposure to pesticides used for agriculture. Of 243 hospital charts that indicated pesticide exposure, only 13 involved workplace exposures; and just 10 (including six of the workplace exposures) involved agricultural-use pesticides. Among poison control consultations, 113 of 547 pesticide exposures occurred in the workplace, and 67 (including 49 occupational exposures) concerned exposure to agricultural-use pesticides. Suicide attempts and early childhood exposures were major sources of hospitalization and poison control consultations, but were practically absent from the PISP.

We recognized from the beginning that exposure as part of a group was an important aspect that we had to consider in analysis. We did not anticipate that it would be the strongest determinant of reporting to PISP. We found that the PISP had records of every

episode we located in any source in which four or more people had been exposed. This included all combinations of relation to workplace exposure and agricultural use.

The next strongest predictor of reporting proved to be agricultural use of the implicated pesticides. For both hospital and poison control records, the PISP had entries corresponding to roughly half of the cases that indicated exposure to pesticides used for agriculture and not responsible for group exposures.

We expected that the PISP's reliance on workers' compensation records would make occupational exposure an important factor. This was true, though to a lesser extent than we had anticipated. Workplace exposure did not enhance reporting of exposures to agricultural-use pesticides. When other pesticides were involved, about 16% of non-group workplace exposures were reflected in the PISP.

The PISP had records corresponding to only five of 226 hospitalizations and 14 of 396 poison control consultations that concerned pesticide exposures unrelated to work, agriculture, or groups. Almost all of these exposures occurred at residences. Suicide attempts and early childhood exposures were particularly unlikely to be reported.

This study found no evidence that the PISP missed any episode that exposed more than three people to pesticides. Among episodes that exposed three people or fewer, exposures to agricultural-use pesticides were the most likely to have been reported. The PISP lacks information on non-occupational cases, especially those involving intentional exposures and pre-school-aged children.

The frequency and severity of health effects from pesticide exposure has become a subject of public discourse in the United States[1-3]. Surveys by the U.S. General Accounting Office conclude, however that valid data remain sparse[4,5]. Routinely collected data sets such as hospital discharge abstracts, which use the International Classification of Diseases to describe the causes of mortality and morbidity, remain major sources of information on the epidemiology of pesticide toxicity[5,6]. The United States Environmental Protection Agency (U. S. EPA) supplements these resources by consideration of data from poison control contact logs, and from the California Pesticide Illness Surveillance Program (PISP)[6].

The PISP is the oldest and largest state-mandated surveillance program for health effects of pesticides in the United States. In 1971, legislation established a requirement to report "any disease or condition" that a physician "knows or has reason to believe" derived from pesticide exposure. The program took shape over the following decade, coming to be housed in what is now the California Department of Pesticide Regulation (DPR). It now maintains a database of more than 40,000 investigated instances of health conditions suspected of relation to pesticide exposure, dating back to 1982. It supplies data to internal and federal regulatory programs as well as to industry, public interest groups, and individual citizens.

The present work was undertaken with the intention of integrating information from all major data sources to obtain a clearer view both of the nature of the health effects of pesticides and of the characteristics of the individual data sources. In particular, we hoped to clarify interpretation of PISP data with respect to efficiency of case identification and structural bias in the program. This publication reports the results of reviewing California inpatient hospital charts and poison control consultations for the period 1994 – 1996, and comparing that information with the reports to the PISP for the same period.

The literature on pesticide toxicity provides few parallels for this effort. Previous publications have summarized automated data collected nationally[7] and several have reviewed data from multiple sources to develop profiles of pesticide toxicity for specific areas and timespans[8-10]. For a six-month period, one regional poison control center[11] identified consultations about occupational exposures, and attempted to locate them in surveillance records. Outside the United States, two comparisons of data sources[12,13] have identified substantial under-reporting of pesticide-related morbidity to mandated surveillance programs.

The work described here represents the first attempt at a quantitative evaluation of the PISP since Kahn's 1976 report[14]. That work compared surveillance counts of field worker illnesses to self-reports elicited by a pair of unpublished surveys from two California agricultural communities.

This report presents descriptive information on the full range of pesticide morbidity identified in California by review of hospital records, poison control logs, and PISP data. The investigation was performed by the PISP lead scientist as part of a doctoral dissertation, with the assistance of a committee of faculty of the University of California

at Davis. Funding was supplied by the U. S. EPA and the National Institute for Occupational Safety and Health.

Materials and Methods

Data sources

Inpatient Discharges: We selected hospital records from files maintained by the Office of Statewide Health Planning and Development (OSHPD). The State of California requires all nonfederal licensed hospitals to report data on all inpatient discharges semi-annually to OSHPD. The format prescribed for these reports includes locations for up to 25 diagnosis codes of the International Classification of Diseases, ninth revision, clinical modification (ICD-9 CM), and five additional locations for external cause of injury codes. In each category, one code is designated as principal.

The World Health Organization publishes the ICD coding system, which is now in its ninth revision (ICD-9). The U. S. Public Health Service publishes an extension for use in American hospitals, ICD-9 CM, that provides additional specificity for some conditions. During the study period, California hospitals coded their discharges using ICD-9-CM, which is fully compatible with ICD-9, and identical to it with respect to the codes used in this work.

Poison Control: Of the six poison control centers that served California during the study period, only the Central Valley Regional Poison Control Center collected narrative information for the full study period from 1994 through 1996. This center serves the most heavily agricultural area of the state. It contributed records for the entire period.

Enhanced data collection was adopted in September 1995 by the University of California Davis Medical Center Regional Poison Control Center, which served the northeast quadrant of California. Four other poison control centers served other California regions during the period of interest, but their data were considered unusable because, besides lacking narrative, they had not been subject to standard poison control edit and verification procedures.

PISP: The PISP maintains electronic files of all cases identified as potentially related to pesticide exposure. State law requires California physicians to report any disease or condition that they know or have reason to believe derived from pesticide exposure. The PISP supplements these reports by reviewing doctors' reports on patients treated under workers' compensation (insurers forward these reports to the Department of Industrial Relations, which cooperates with the PISP through a memorandum of understanding). The PISP also includes cases identified by other means, such as news reports or direct complaints.

All the PISP records had been investigated by the Agricultural Commissioner of the county where exposure occurred. Scientists employed by the California Environmental Protection Agency's Department of Pesticide Regulation evaluated and coded findings from these investigations.

Criteria for record selection
Inpatient Discharges: Hospital records were selected if any of their diagnosis fields held ICD-9 CM codes 989.1 through 989.4 or E861.4, E863.0 through E863.9, E950.6, or E980.7. These seventeen codes constitute the "specific codes". Code E861.4, "accidental poisoning by disinfectants", was included as a specific code, since disinfectant products are regulated as pesticides. For regulatory purposes, this class of pesticides is referred to as "antimicrobial", and described as including sanitizers and disinfectants. The three terms are used interchangeably.

We also investigated hospital records that carried any of a broader group of "general codes," to maintain comparability to previous work and to collect as many pesticide-related cases as possible. We selected records that carried any of 42 diagnostic codes or 42 external cause of injury codes that indicate toxicity or chemical injury by unclassified substances or by classes of substances that include pesticides among other products (see Appendix A). Codes for metals and caustic materials were included based partially on Hayes's procedures. Inclusion of codes for irritant effects and for burns of internal organs was suggested by a 1985 study of hospitals in central Nebraska[15]. The ninth revision of ICD provides no code for fluorides, so it was not possible to replicate that aspect of Hayes's work.

For convenience of analysis, the codes were further subdivided into ten groups (identified in Appendix A). Among specific codes, antimicrobials and strychnine products were separated from other pesticide codes. Subcategories of general codes included metal toxicity, toxic effects of cleaning agents, caustics and corrosives, toxic effects of alcohols, miscellaneous toxicants, other or unspecified toxicants, and irritant effects (without reference to specific toxicants).

Poison Control: We selected poison control records for review if they carried a generic toxicant code likely to indicate pesticide exposure, indicated involvement of a medical professional, and included narrative fields to provide details of exposure, symptomatology, and clinical course. A poison control analyst assisted us in identifying generic toxicant codes likely to represent pesticides. We considered that medical professionals had been involved in calls recorded as having come from health care facilities, in those regarding patients in or en route to health care facilities, and in those in which the patient had been referred to a health care facility.

We made no attempt to ascertain pesticide toxicity that did not result in medical consultation. Because the legal requirement to report such cases is imposed on physicians, the PISP accepts medical consultation as a legislatively imposed threshold. Any inquiry into health effects not evaluated medically faces a serious challenge in validating the relevance of reported events.

PISP: All PISP records were considered eligible for inclusion in this study. The database records only cases in which pesticide exposure is suspected of causing or contributing to adverse health effects.

Sample selection

Inpatient Discharges: The California OSHPD provided a file that contained all 12,830 hospital discharge records from 1994 through 1996 that carried codes of interest in any of 25 locations. We selected a two-stage stratified probability sample of discharges from this file for detailed review. In the first stage, we selected a sample of 100 hospitals stratified on the number of cases with specific codes identified per hospital. Twenty-five hospitals were selected randomly from each of four strata, including one composed of hospitals that reported no discharges with specific codes, but only general codes. Hospitals were not eligible for sampling if they reported no cases with either specific or general codes suggestive of pesticide-related illness or injury.

After the sample was selected, we contacted each hospital to ascertain the appropriate executives from whom to request participation. Letters explaining the project were sent to the Chief Executive Officer and the Director of Medical Records (or equivalent positions) at each hospital. After three weeks, hospitals that had not responded were contacted by telephone. We made a minimum of eight attempts to contact each nonresponding hospital, using telephone, facsimile, and electronic and conventional mail. Several medical records directors deferred decisions regarding hospital participation to the hospital's Risk Management or Quality Improvement departments. We followed up with certified letters to address specific concerns from these sources, and to facilitate local Institutional Review Board (IRB) approval, as appropriate.

Within selected hospitals, all records with specific pesticide codes were requested. Records with only general codes were grouped into three strata: Records coded for cyanide or metal toxicity held special interest for historical reasons, and constituted one stratum. Another stratum segregated records selected based on two especially common codes: toxicity of ethyl alcohol (980.0), which is an active ingredient in more than 100 registered pesticide products, and self-inflicted poisoning by other and unspecified solid and liquid substances (E950.9). All other general codes were grouped in the third stratum. Up to five records were requested from each stratum. From strata containing more than five records, a sample of five was selected randomly.

Poison Control: Poison control review began with the earliest records, those concerning consultations at the Fresno center early in 1994. Review of the first 100 records demonstrated the impracticality of reviewing all 2,756 records received. The file was then divided into two strata, one consisting of the most severe cases, and one of all others. Severe cases included fatalities, outcomes coded as "major", and all inpatient admissions (both medical and psychiatric). We reviewed all records in the severe stratum and a randomly selected 20 percent sample of the others. On statistical advice, we included the initial 100 records reviewed as a third stratum.

For the final six months of the study period, the PISP contracted with the Central Valley Regional Poison Control Center to explore the feasibility of poison control assistance in reporting pesticide cases to the PISP. During 1996, this center mediated transmission of 57 cases under this contract. Data received from poison control did not identify these cases. Those reviewed in this investigation were recognized after merging with PISP data and segregated in analysis.

PISP: Data on all PISP cases identified between 1994 and 1996 were converted electronically to the format used for recording hospital and poison control reviews. Because case reports sometimes arrive late, we also converted records received during 1997 that referenced exposures that occurred earlier. To maintain consistency with the standards applied to hospital and poison control records, all PISP records were included in analysis. Some of them had been evaluated after investigation as involving no pesticide. Their presence in the database, however, documented some consideration that exposure to a pesticide product had contributed to development of health problems.

Review and Coding

We reviewed hospital and poison control records individually to identify the toxicants involved and to determine the source of exposure. When case reports could be identified as derived from a common event, such as pesticide drift onto a group of people, we used the case identifier of the earliest case encountered as an event identifier, and entered it as a reference number in each associated record. Episodes involving five or more people receive particular attention from the PISP, so were identified as an analytic category.

Records were classified as pesticide-related if the responsible health professional(s) documented any consideration that exposure to a pesticide product (as defined by the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA))[16] had contributed to the health problems about which medical professionals were consulted. The FIFRA definition states that pesticides include "any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest. …". This definition explicitly includes microbes as pests and the products that control them as pesticides, except when regulated as therapeutic agents by the Food and Drug Administration. Ingestions of household bleach were not classified as pesticide cases, since the product was unlikely to have been registered as a pesticide, and since there was clearly no intent to use the product as a pesticide.

Pesticide exposures were classified as intentional if the record indicated that the person intended toxic exposure to occur. The following exposures were classified as unintentional: exposures incidental to using a pesticide for its intended purpose, exposures that arose from misunderstanding about the nature of the product, self exposures of children up to 12 years old, and older individuals who exposed themselves while compromised by dementia, intoxication, or an acute psychotic episode. Exposure in attempting to treat delusional parasitosis, however, was classified as intentional.

Pesticides were identified as agricultural if their use was intended to contribute to production of an agricultural commodity. Exposures were classified as occupational if they occurred while the affected people were at work. Specific work tasks did not figure in determining occupational exposure.

One investigator reviewed and coded all poison control records. Two specially trained nurse-abstractors reviewed charts provided by cooperating hospitals and recorded the substances to which patients had been exposed, the mechanism and situation of their exposure, and the documentation available to substantiate exposure. They also abstracted signs and symptoms from the medical record, the results of significant diagnostic tests and therapeutic efforts, and indicated whether the case included consultation with specialists such as poison control centers, academic toxicologists, or government health and safety agencies. For records that contained no reference to pesticides, abstraction was limited to a brief narrative and list of toxicants identified. All of this information was entered directly into a computerized database with built-in error checks and detailed guidelines, based on the National Institute for Occupational Safety and Health's definitions of standardized variables for state surveillance programs. The first author independently abstracted a randomly selected sample of hospital charts. All identified discrepancies were resolved through group meetings and guideline revisions.

After coding, all cases that documented any consideration of pesticide involvement were merged into a file containing records collected during the study period by the California Pesticide Illness Surveillance Program (PISP). A program extracted from the existing file all entries that occurred within two weeks of the event under consideration, and all that involved a victim of comparable age (within two years) to the current case. For each entry extracted, a similarity score was constructed by summing one half of any difference in age (in years), one third of any difference in date of exposure (in days), and one for each discrepancy in sex, occurrence of hospitalization, fatal outcome, occupational exposure, intent (self-inflicted vs. accidental), or exposure in the course of using the pesticide.

The investigator then reviewed a display of the event under consideration juxtaposed with an ordered list of potential matches, including names. Before a case could be entered as matched, the program displayed a complete list of variables, including identity of the pesticides involved, for the case under consideration and the proposed match. The investigator then made a final decision either to add the case as a separate event or to register it as another identification of an event already recorded. This produced a file in which one record represented each known event of medical consultation concerning possible health effects of pesticide exposure. When data sources differed regarding details of an event, information from the source indicating the greater level of certainty was maintained in the merged file.

Analyses were performed using Stata for Windows® statistical software, version 6.0, Stata Corporation, College Station, Texas. Case weights were computed as the inverse of the sampling probability, that is, as the ratio of the total number of entries in a stratum to the number of entries reviewed from that stratum. For hospital cases, this procedure was applied separately to hospital strata and to case strata within hospitals. The final case weight for hospital cases was computed as the product of the weights for the hospital and for the case within the hospital, and the hospital was identified as the primary sampling unit. Survey commands applied these weights to generate unbiased estimates of probabilities, total frequencies, and associated standard errors.

Results

Among the 100 hospitals sampled, 72 ultimately agreed to participate in the study. Six additional hospitals were still awaiting approval from local IRBs when recruitment ended, and were excluded for that reason. Of the remaining 22 nonparticipants, six had closed and efforts to locate their records were unsuccessful. Six psychiatric hospitals declined to participate because of confidentiality concerns. The 72 participating hospitals provided 944 of the 1035 records (91.2%) requested from those hospitals, although some hospitals only provided partial records because of confidentiality or cost concerns. Hospital records reviewed were found to resemble the full dataset closely with respect to distributions by age, sex, severity, disposition following hospitalization, and length of hospital stay. All regions of the state were represented in proportion to their contributions to the dataset with the exception of the San Francisco Bay area, where only eight hospitals agreed to participate of the 14 from which we requested participation.

We reviewed 944 charts from 72 hospitals, and records of 741 poison control consultations. We identified some reference to pesticides in the charts of 243 hospitalized patients who were discharged alive, and in poison control records for 547 consultations that did not indicate the subject died. Application of sampling weights produced estimates of 1,295 non-fatal hospitalizations (standard error = 173) and 2012 non-fatal poison control contacts (standard error = 50). A related publication[17] describes information on 24 pesticide fatalities identified from 1994 through 1996. The PISP investigated 6,692 non-fatal case reports from 1994 through 1996, which were formatted electronically for inclusion in this analysis. We identified a total of 7,380 individual medical consultations in which pesticide exposure was suspected, of which 2,335 were involved in 365 group episodes. Groups ranged in size from two to 243 individuals.

Qualitative characteristics

All three information sources identified more male than female poisoning victims and all showed a broad peak in early adulthood (Table 1). All recorded high proportions of exposures to insecticides and antimicrobials among all classes of victims.

PISP data differed from hospital and poison control data in recording primarily occupational exposures (87%), and in collecting a higher percentage of cases involving exposure to agricultural-use pesticides (39%). Among poison control entries, weighted results indicated 20% were occupational and 13% agricultural. Weighted results for hospital discharges identified agricultural exposures in 5%. They indicated that 15% were occupational, a result that derives primarily from a single case sampled with very low probability. Excluding that case reduces the estimate of the occupational proportion to 5%.

Fewer than 1% of PISP cases involved intentional exposures, while nearly 9% of poison control contacts and 27% of hospital admissions concerned intentional exposures. Early childhood exposures (0 to 4 years) were almost completely absent from the PISP (0.3%), but constituted the largest age category of hospital (21%) and poison control (31%)

records. Among young children, one- and two-year olds predominated in both hospital and poison control records (Table 2).

About one-third of intentional and childhood exposures involved rodenticides, which were very rare among unintentional adult exposures (less than 2%). Among poison control contacts, 92% of patients remained asymptomatic following exposure to anticoagulant rodenticides. The majority (68%) of hospital admissions for anticoagulant rodenticide exposure also had no symptoms apart from those caused by therapeutic efforts (e.g. vomiting after ipecac administration). Among both hospital and poison control records, of the non-occupational cases that identified the location of exposure, at least 90% occurred at residences (lower bound of 95% confidence interval).

File linkage
PISP records were located for only 11 of 243 non-fatal hospitalizations (Table 3) and 78 of 547 poison control contacts (Table 4). Involvement in a group episode was the strongest predictor of matching, followed by exposure to agricultural-use pesticide and occupational exposure.

Hospital records included only 10 exposures to agricultural-use pesticides, of which six were occupational. Another seven hospitalizations involved suspicion of occupational exposures to non-agricultural pesticides. Half of the agricultural exposures were identified in the PISP. The proportion was consistent for occupational and non-occupational exposures, and for exposures that occurred in the heavily agricultural San Joaquin Valley (four) and in other parts of California (six). One of the seven non-agricultural occupational exposures matched to a PISP record.

Weighted estimates also showed that hospital admissions for agricultural exposures had approximately a 50% probability of being reported (point estimate = 0.47, standard error = 0.12), while the probability for non-agricultural exposures was less than 5% (point estimate = 0.03, standard error = 0.02). Although occupational exposures were several times as likely to match to PISP records as non-occupational exposures, confidence intervals were wide and the effect was not statistically significant.

Among poison control consultations, agricultural exposures showed greater than a 50% likelihood of being reported (point estimate = 0.68, standard error = 0.06). Occupational setting had no significant effect on reporting of agricultural exposures. Weighted estimates indicated that when exposure was non-agricultural, occupational exposures were more likely to be reported (point estimate = 0.18, standard error = 0.06) than non-occupational exposures (point estimate = 0.04, standard error = 0.01). These figures were revised upon recognition that poison control records had not identified agricultural and occupational connections for some cases in which investigation had documented such connections. The change raises the estimate for agricultural exposures and lowers the estimate for non-agricultural occupational exposures.

Among the 547 non-fatal pesticide-related poison control entries reviewed, 75 were contributed by the Central Valley Regional Poison Control Center during the period that it was under contract to assist in reporting cases to the PISP. The Center had mediated reporting for 14 of those 75 (of which seven concerned exposures to agricultural pesticides). Exclusion of the fourteen cases reported to the PISP by poison control did not materially affect estimates of reporting probability. The PISP independently identified 11 of the 61 cases that the poison control center might have forwarded but did not, including nine of the 11 cases involving agricultural-use pesticides.

File linkage subpopulations
Each data source provided some information that indicated the likelihood of finding the same event recorded in other data sources. We considered several subsets of cases in an effort to clarify interpretation of matching.

PISP/hospitals: The PISP recorded inpatient admission for 79 non-fatal cases, of which 14 identified the admitting facilities as hospitals that participated in this study. Hospital records were received for four of these. One other apparently was requested, but the hospital could not locate the chart. Of the other nine, the PISP had recognized five (after investigation) as having causes other than pesticide exposure; and three of the remaining four cases had characteristics that obscured their relation to pesticides. The PISP did not record hospital admission for three cases that matched to hospital records, and identified hospitals other than those that participated in this study in four other matched cases. In summary, we found hospital matches for four of 14 PISP records for which we expected matches, four of 65 others in which we knew the people had been admitted to hospitals, and three of 6,613 that did not indicate hospitalization.

PISP/poison control: Based on county and date of occurrence, 2,257 PISP records might have been included in the available poison control data. No information indicated that poison control had or had not been consulted in these cases. Seventy-six of them actually were located in poison control files, including the 14 cases reported via poison control. Two of seven calls from outside the centers' catchment districts also proved to have been reported.

Poison control/hospital: Poison control records identified 112 non-fatal inpatient admissions to either medical or psychiatric facilities. The records provided institution names for 87 of these, of which 28 identified hospitals that participated in this study. Hospital charts were received for ten of the 28, for three of the 58 for which poison control records indicated admission at a different location, and for one of the 25 listed by poison control as hospitalized at an unspecified location. Hospital charts were also received for two of 435 poison control entries that did not indicate hospitalization.

Hospital/poison control: Of the 243 non-fatal pesticide hospitalizations reviewed, just 32 occurred in the catchment areas of participating poison control centers and during the time for which poison control data were available. Abstractors located comments in 18 of these charts indicating that poison control had been consulted, although they could not identify which center took the call. Corresponding poison control records were identified for 12 of the 18. Poison control records were also found for 4 of the 14 charts that did not document poison control consultation.

Group exposures: Of the 365 episodes that exposed two or more people, 15 were identified in both PISP and poison control records. A hospital chart was received for one member of one occupational group episode (a person for whom PISP records did not indicate hospitalization) and for two members of a family. No group of more than three individuals failed to match to the PISP. Involvement in a group episode was the strongest predictor of presence in PISP records.

Discussion

We began this work with the knowledge that hospital discharge records carried pesticide diagnosis codes more frequently than the PISP received notification of hospitalization for health effects of pesticides. We intended to investigate the types of products and exposures involved in these hospitalizations, together with such data as poison control centers could provide, and to use the information to clarify interpretation of the PISP data.

The PISP has a recognized bias towards occupational exposures, since its case identification relies heavily on review of documents submitted through workers' compensation. Because County Agricultural Commissioners have strong ties both with the PISP and with the agricultural community, we suspected that they might learn of agricultural exposures and forward them to the PISP. This would account for the higher probability of locating agricultural cases.

We found that hospital and poison control identified many health consultations that qualified for reporting to the PISP and were not reported. Most of these unreported consultations involved residential exposures.

Our findings agreed with previous work on frequency of hospitalization for health effects and exposure circumstances. Like investigators in North Carolina and South Carolina[8,18-21], we found that hospitalizations included roughly comparable numbers of children, suicide attempts, and unintentional adult exposures. The low number associated with occupational exposures agrees with the South Carolina survey from 1992 – 1996[21], which found occupational exposures occurring less frequently than in earlier surveys. Unlike the South Carolina investigators, who received cooperation from over 90% of hospitals, we were able to persuade only 72 of 100 sampled hospitals to participate. Six psychiatric institutions declined because of confidentiality concerns, probably leading to under-representation of intentional exposures.

A nationwide probability sampling of hospitals[7] produced an estimate of 25,418 pesticide hospitalizations from 1985 through 1990, based on identification of 138 cases with pesticide-specific codes. If the same rate of hospitalization (15.25 per million annually) applied to California in 1994 – 1996, we would expect about 450 annual hospitalizations in California. We found a somewhat smaller number: Over the three year period, pesticide-specific codes were assigned to 1011 hospital discharges, and were the principal diagnoses for 883. Excluding the code for disinfectants, 896 discharges received pesticide-specific codes, of which 780 were the principal diagnosis. Our detailed review of a sample that included discharges with general codes for toxicity produced an estimate of 1,295 non-fatal pesticide-related hospitalizations (standard error = 173), including 420 attributed to antimicrobial pesticides.

The results of file linkage cast some doubt on the completeness of case ascertainment using diagnostic coding. Both poison control logs and the PISP identified hospitalizations at participating institutions, but we located fewer than half of them among discharge records.

Some cases of interest have little likelihood of identification by codes for toxicity. DPR, as a regulatory agency, takes a different view of products and events than clinicians do. For instance, the PISP learned through agricultural authorities of a crop duster pilot injured in a crash. Since the pesticide (sulfur) initiated the event by catching fire, the PISP evaluated this as a definite instance of health effects caused by pesticide use. In other cases, patients transferred to participating hospitals after recovery from pesticide effects, or were treated for conditions that proved unrelated to pesticide exposure.

We feel more concern about the number of cases for which hospitalization was documented by poison control, but for which no corresponding hospital record was located. A follow-up effort to locate the charts of those individuals would be required to distinguish between hospital failure to assign pesticide codes and inaccurate hospitalization information in poison control records. Our review documented the potential for misunderstandings at both hospitals and poison control centers.

This work successfully characterized the cases identified by routine coding but absent from the PISP: The majority of them derive from residential exposures, and they include substantial numbers of children and adults who used pesticides in suicide attempts (intentional exposures). Cases in the latter exposure categories had less than 1% probability of being reported to the PISP, and their absence accounted for the absence of exposures to rodenticides in the PISP. Even excluding intentional and early childhood exposures, the majority of hospital admissions and poison control contacts involved exposures that were neither occupational nor agricultural. Such cases were only slightly more likely than intentional and early childhood exposures to be identified by the PISP (estimate = 0.04, standard error = 0.02).

Small numbers of agricultural exposures among hospitalizations and poison control contacts may be explained in several ways. The difficulties agricultural workers encounter in finding medical care have been documented[22], but can be overcome in some cases. In 1999, California's 715 primary care clinics reported 948,636 contacts with 307,916 patients who were agricultural workers or dependents of agricultural workers[23]. Data currently collected provide no indication of whether the clinic contacts relate to pesticide exposure.

It may be that even farm workers who present to clinics would be reluctant to accede to hospital admission. Since most lack health insurance, they are limited in choice of hospitals, and some must travel a substantial distance to reach one that will admit them. Their limited representation among poison control contacts may reflect greater experience and expertise on the part of clinic staff who see fieldworkers regularly, and who may feel less need to consult poison control.

File linkage identified so few cases from more than one source that it is nearly impossible to evaluate interactions. The effect of involvement in group episodes, however, appears to be so dominant that it makes little sense to discuss other effects without taking it into account. We located no group of more than three exposed individuals without corresponding records in the PISP. Of the seven hospitalizations for non-agricultural occupational exposures, the only one to match to a PISP entry was the one involved in a group episode. Among the 78 case reports from poison control logs that matched to PISP entries, 42 concerned people exposed in group episodes. Exposures to agricultural pesticides were identified in 36 matched entries, including 24 involved in exposures of groups.

Evaluating the role of group exposures presents special problems, since neither hospital records nor poison control logs provide any systematic way to identify them. We had no way to sample groups, but could only identify them after reviewing sampled cases. Poison control records include a variable to indicate multiple victims, but they do not specify the number involved or identify related cases, and we found the indicator to be unreliable.

Case narratives did indicate involvement in group episodes for all of the hospital and poison control cases that matched to group episodes in the PISP, and also identified seven groups with total of 15 people involved in episodes unknown to the PISP. The extent to which sampling limited our ability to identify group episodes remains an open issue. Nevertheless, among hundreds of medical consultations involving pesticide exposure, we located no indication that the PISP had overlooked any episode in which four or more people were exposed. We question whether groups of four are really so well publicized that all groups of four or more come to the PISP's attention. It seems, though, that there is a size threshold above which news reports virtually guarantee that the PISP gets word of the event.

Excluding cases involved in group episodes, poison control data gave a weighted estimate of 0.52 (standard error = 0.09) for the probability of finding PISP records corresponding to poison control contacts about agriculturally related occupational exposures, and 0.16 (standard error = 0.06) for non-agricultural occupational exposures. This is compatible with the estimate of 0.17 (confidence interval 0.05 – 0.28) reported by Blanc et al.[11] for occupational exposures.

Although these probabilities of reporting may seem discouragingly low, they are typical of surveillance programs generally. Teutsch and Churchill[24] report that "Under-reporting is a consistent and well-characterized problem of notifiable-disease reporting systems… In the United States, estimates of completeness of reporting range from 6% to 90%"

These results provide limited evidence that the PISP collects approximately half of the events in which medical professionals evaluate health effects that follow exposure to agricultural pesticides, and a smaller proportion of those associated with non-agricultural occupational exposures. In spite of the small numbers, the agreement between hospital data and poison control data gives some credibility to 50% as a reasonable approximation to the rate at which the PISP captures medical consultations about agricultural pesticide exposures.

Interpreting this result as a capture/recapture[25-27] census suggests that about twice as many exposures to agricultural-use pesticides result in medical consultation as the PISP learns of. Such a conclusion depends on the assumption that doctors who do not consult poison control have the same rate of reporting as those who do, and that patients who are not admitted to hospitals have the same probability of being reported as those that are. A priori reasoning questions both of those assumptions, but in opposite directions: Physicians with experience managing pesticide exposures have less need than others to consult poison control, so those who consult poison control may have less familiarity with regulatory requirements and a lower probability of reporting. Patients admitted to hospitals generally have more severe problems than those who are not, and come to the attention of more professionals, factors that should increase the probability of reporting.

We have still less certainty about the total number of consultations concerning non-agricultural, non-occupational pesticide exposures. We found evidence of many such events, without enough overlap between sources to develop an estimate of the completeness of any of them.

These results clearly demonstrate the importance of seeking outside resources to validate and clarify the results of surveillance. We now recognize the likelihood that numerous California medical consultations each year concern domestic exposures and are not reported to the PISP. The PISP has continued to pursue cooperation with poison control centers to enhance its coverage and value.

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Table 1: Profiles of California Medical Consultations with Non-Fatal Outcomes, 1994 - 1996, In which Pesticide Exposure was Suspected; by Source of Information

	Total PISP		Hospital Discharge		Poison Control Eligible PISP[a]		Poison Control Logs	
	Count	Percent	Weighted Estimate of Statewide Total	Percentage of Total Hospital Estimate	Count	Percent	Weighted Estimate of Total from Participating Centers	Percentage of Total Poison Control Estimate
Intentional Exposure								
Male	33	70	220 (40)	63	4	57	101 (19)	57
Female	14	30	129 (26)	37	3	43	75 (17)	43
Total	47	100	349 (47)	100	7	100	176 (25)	100
Exposure Not Documented as Intentional								
Male	3973	60	589 (157)	62	1545	69	1115 (56)	61
Female	2617	39	357 (84)	38	685	30	715 (50)	39
Unknown Sex	55	1	0	0	20	1	6 (5)	0.3
Total	6645	100	946 (171)	100	2250	100	1837 (53)	100.3

Table 1, Page 2	Total PISP		Hospital Discharge		Poison Control Eligible PISP[a]		Poison Control Logs	
	Count	Percent	Weighted Estimate of Statewide Total	Percentage of Total Hospital Estimate	Count	Percent	Weighted Estimate of Total from Participating Centers	Percentage of Total Poison Control Estimate
Intentional Exposure								
Age (Years)								
0 - 4	0	0	0	0	0	0	0	0
5 - 14	0	0	10 (8)	3	0	0	18 (9)	10
15 - 24	6	13	82 (30)	23	0	0	56 (15)	32
25 - 34	13	28	97 (25)	28	3	43	39 (12)	22
35 - 44	17	36	85 (23)	24	3	43	31 (10)	18
45 - 54	7	15	40 (17)	11	1	14	17 (8)	10
55 - 64	1	2	17 (12)	5	0	0	7 (5)	4
65 - 74	2	4	13 (12)	4	0	0	0	0
75 - 84	0	0	2 (2)	1	0	0	0	0
85 +	0	0	3 (2)	1	0	0	1 (1)	1
Unknown	1	2	0	0	0	0	6 (5)	3
Total	47	100	349 (47)	100	7	100	176 (25)	100

Table 1, Page 3	Total PISP		Hospital Discharge		Poison Control Eligible PISP[a]		Poison Control Logs	
	Count	Percent	Weighted Estimate of Statewide Total	Percentage of Total Hospital Estimate	Count	Percent	Weighted Estimate of Total from Participating Centers	Percentage of Total Poison Control Estimate
Exposure Not Documented as Intentional								
Age (Years)								
0 - 4	22	0.3	277 (60)	29	1	0.04	625 (48)	34
5 - 14	142	2	29 (15)	3	64	3	180 (29)	10
15 - 24	1138	17	21 (13)	2	429	19	180 (29)	10
25 - 34	1924	29	101 (35)	11	692	31	252 (33)	14
35 - 44	1642	25	220 (82)	23	539	24	293 (35)	16
45 - 54	842	13	24 (10)	3	283	13	132 (24)	7
55 - 64	377	6	172 (137)	18	133	6	56 (16)	3
65 - 74	62	1	61 (28)	6	14	1	47 (14)	3
75 - 84	12	0.2	41 (20)	4	4	0.2	24 (10)	1
85 +	5	0.1	0	0	3	0.1	16 (9)	1
Unknown	479	7	0	0	88	4	31 (12)	2
Total	6645	100.6	946 (171)	99	2250	101.34	1837 (53)	101

Table 1, Page 4	Total PISP		Hospital Discharge		Poison Control Eligible PISP[a]		Poison Control Logs	
	Count	Percent	Weighted Estimate of Statewide Total	Percentage of Total Hospital Estimate	Count	Percent	Weighted Estimate of Total from Participating Centers	Percentage of Total Poison Control Estimate
Exposure Not Documented as Intentional, Age Less Than Five Years								
Cholinesterase Inhibitors	8	36	41 (17)	15	0	0	68 (18)	11
Other Insecticides	2	9	42 (21)	15	0	0	116 (23)	19
Herbicides	1	5	2 (2)	1	0	0	5 (5)	1
Fungicides	0	0	0	0	0	0	0	0
Fumigants	1	5	2 (2)	1	0	0	0	0
Anti-coagulant Rodenticides	3	14	49 (13)	18	0	0	312 (37)	50
Other Rodenticides	0	0	40 (17)	14	0	0	15 (9)	2
Antimicrobials	0	0	102 (49)	37	0	0	94 (21)	15
Miscellaneous Pesticides	1	5	2 (2)	1	0	0	7 (5)	1
Combinations	1	5	2 (2)	1	0	0	2 (1)	0.3
Unknown	2	9	0	0	0	0	6 (5)	1
None	3	14	0	0	1	100	0	0
Total	22	102	277 (60)	103	1	100	625 (48)	100.3

Table 1, Page 5	Total PISP		Hospital Discharge		Poison Control Eligible PISP[a]		Poison Control Logs	
	Count	Percent	Weighted Estimate of Statewide Total	Percentage of Total Hospital Estimate	Count	Percent	Weighted Estimate of Total from Participating Centers	Percentage of Total Poison Control Estimate
Exposure Not Documented as Intentional, Age Five Years or More								
Cholinesterase Inhibitors	810	12	226 (138)	34	321	14	303 (36)	25
Other Insecticides	1067	16	81 (24)	12	446	20	253 (33)	21
Herbicides	308	5	42 (19)	6	136	6	173 (30)	14
Fungicides	330	5	0	0	195	9	20 (9)	2
Fumigants	280	4	28 (17)	4	156	7	42 (14)	3
Anticoagulant Rodenticides	1	0	15 (12)	2	0	0	15 (9)	1
Other Rodenticides	3	0	0	0	0	0	1 (1)	0.1
Antimicrobials	1779	27	242 (85)	36	357	16	286 (35)	24
Miscellaneous Pesticides	74	1	0	0	27	1	15 (9)	1
Combinations	404	6	0	0	151	7	50 (15)	4
Unknown	345	5	34 (17)	5	102	5	54 (16)	4
None	1222	19	0	0	358	16	0	0
Total	6623	100	669	99	2249	101	1211 (57)	99.1

Table 1, Page 6	Total PISP		Hospital Discharge		Poison Control Eligible PISP[a]		Poison Control Logs	
	Count	Percent	Weighted Estimate of Statewide Total	Percentage of Total Hospital Estimate	Count	Percent	Weighted Estimate of Total from Participating Centers	Percentage of Total Poison Control Estimate
Agriculturally-related								
Occupational	2374	35	37 (25)	3	1389	62	187 (29)	9
Non-Occupational	264	4	21 (13)	2	187	8	71 (18)	4
Non-Agricultural								
Occupational	3468	52	162 (136)	13	556	25	219 (30)	11
Non-Occupational	586	9	1074 (131)	83	115	5	1535 (57)	76
Total	6692	100	1295 (173)	101	2257	100	2012 (50)	100

a. PISP cases that occurred in the catchment areas of participating poison control centers during the period for which poison control data were available.

Table 2: Age and Sex Distribution of Children Less than Five Years Old Among Non-Fatal California Pesticide-Involved Hospital Discharges and Poison Control Consultations, 1994 - 1996				
	Weighted Estimate of Statewide Hospital Total (standard error)		Weighted Estimate of Total from Participating Poison Control Centers (standard error)	
	Male	Female	Male	Female
0 – 11 Months	3 (2)	8 (5)	31 (12)	15 (7)
12 – 23 Months	106 (52)	49 (13)	136 (25)	98 (22)
24 – 35 Months	70 (29)	6 (3)	112 (22)	116 (23)
3 - 4 Years	18 (13)	17 (8)	62 (17)	55 (16)

Table 3: Summary of Linkage Between Hospital Records and PISP					
	Hospitalized PISP Cases (a)		Hospital Discharges		
	Not Matched to Hospital Chart	Matched to Hospital Charts	Weighted Estimate of Statewide Total Matched (standard error)	Weighted Estimate of Match Probability (standard error)	Weighted Estimate of Statewide Total Unmatched
Exposure of just one person	60	8	66 (29)	0.005 (0.002)	1222 (173)
Exposure of 2 - 4 people	4	0	0	0	3 (2)
Exposure of 5 + people	6	1	4 (4)	1 (0)	0
Age Group (Years)					
0 - 4	0	1	1 (1)	0.005 (0.005)	276 (60)
5 - 14	2	0	0	0	39 (17)
15 - 34	20	3	23 (14)	0.08 (0.04)	278 (56)
35 - 64	39	5	41 (26)	0.07 (0.05)	517 (155)
65 +	6	0	4 (4)	0.04 (0.04)	116 (33)
Unknown	3	0	0		0
Total	70	9	70 (29)	0.05 (0.02)	1225 (173)
Male	47	4	45 (20)	0.06 (0.02)	764 (153)
Female	23	5	25 (13)	0.05 (0.03)	461 (81)

Table 3: Summary of Linkage Between Hospital Records and PISP, Page 2					
	Hospitalized PISP Cases (a)		Hospital Discharges		
	Not Matched to Hospital Chart	Matched to Hospital Charts	Weighted Estimate of Statewide Total Matched (standard error)	Weighted Estimate of Match Probability (standard error)	Weighted Estimate of Statewide Total Unmatched
Cholinesterase Inhibitors	21	6	48 (26)	0.14 (0.08)	308 (137)
Other Insecticides	8	1	13 (12)	0.08 (0.07)	159(37)
Herbicides	1	0	0		57 (22)
Fungicides	3	1	0		3 (2)
Fumigants	1	0	0		29 (17)
Anticoagulant Rodenticides			0		113 (20)
Other Rodenticides	1	0	0		94 (26)
Antimicrobials	8	0	0		408 (113)
Miscellaneous Pesticides	1	0	0		2 (2)
Combinations	3	0	0		23 (13)
Unknown	7	0	8 (6)	0.21 (0.14)	31 (16)
None	16	1			
Agricultural-Use Pesticide					
Occupational Exposure	18	2	20 (13)	0.53 (0.05)	18 (13)
Non-Occupational Exposure	1	1	8 (6)	0.38 (0.27)	13 (12)
Other Pesticide Source					
Occupational Exposure	14	1	4 (4)	0.02 (0.03)	158 (136)
Non-Occupational Exposure	37	5	38 (25)	0.04 (0.02)	1036 (129)
Intentional	16	1	2 (2)	0.005 (0.005)	347 (47)
Unintentional	54	8	68 (29)	0.07 (0.03)	878 (170)

(a) Two matched cases did not indicate hospitalization in PISP; a total of 11 cases matched

Table 4: Summary of Linkage Between Poison Control Records and PISP					
	Poison Control Eligible PISP[a]		Poison Control Contacts from Participating Centers		
	Not Matched to Poison Control	Matched to Poison Control	Weighted Estimate of Total Matched (standard error)	Weighted Estimate of Match Probability (standard error)	Weighted Estimate of Total Unmatched (standard error)
Exposure of just one person	1276	35	126 (24)	0.07 (0.01)	1680 (55)
Exposure of 2 - 4 people	156	5	30 (12)	0.48 (0.13)	33 (12)
Exposure of 5 + people	749	36	138 (25)	0.96 (0.03)	5 (5)
Age Group (Years)					
0 - 4	1	0	0	0	625 (48)
5 - 14	55	9	66 (18)	0.33 (0.07)	133 (24)
15 - 34	1095	29	98 (21)	0.19 (0.04)	429 (41)
35 - 64	929	30	102 (21)	0.19 (0.04)	433 (41)
65 +	16	5	12 (7)	0.14 (0.07)	76 (18)
Unknown	85	3	15 (9)	0.4 (0.07)	22 (9)
Total	2181	76	294 (35)	0.15 (0.02)	1718 (55)
Male	1493	56	213 (30)	0.17 (0.02)	1004 (55)
Female	671	17	75 (19)	0.09 (0.02)	715 (50)
Unknown	17	3	6 (5)	1 (0)	0

Table 4: Summary of Linkage Between Poison Control Records and PISP, Page 2					
	Poison Control Eligible PISP[a]		Poison Control Contacts from Participating Centers		
	Not Matched to Poison Control	Matched to Poison Control	Weighted Estimate of Total Matched (standard error)	Weighted Estimate of Match Probability (standard error)	Weighted Estimate of Total Unmatched (standard error)
Cholinesterase Inhibitors	298	26	103 (21)	0.26 (0.05)	291 (34)
Other Insecticides	440	6	46 (15)	0.12 (0.04)	348 (38)
Herbicides	131	5	36 (13)	0.19 (0.06)	155 (26)
Fungicides	194	1	5 (5)	0.24 (0.02)	16 (8)
Fumigants	147	9	42 (14)	1.0 (0)	0
Anticoagulant Rodenticides				0	365 (39)
Other Rodenticides				0	28 (11)
Antimicrobials	346	15	45 (14)	0.11 (0.03)	376(39)
Miscellaneous Pesticides	26	1		0	28 (11)
Combinations	148	3	11 (7)	0.20 (0.12)	44 (14)
Unknown	100	2	5 (5)	0.07 (0.07)	66 (18)
None	351	8			
Agricultural Exposure					
Occupational Exposure	1348	41	148 (25)	0.67 (0.07)	72 (18)
Non-Occupational Exposure	176	11	52 (16)	0.71 (0.11)	21 (9)
Other Pesticide Source					
Occupational Exposure	558	8	37 (13)	0.18 (0.06)	170 (28)
Non-Occupational Exposure	99	16	57 (16)	0.04 (0.01)	1459 (57)
Intentional	4	3	8 (5)	0.05 (0.03)	168 (24)
Unintentional	2177	73	286 (35)	0.16 (0.02)	1551 (56)

a. Cases that occurred in the catchment areas of participating poison control centers during the period for which data were available